

Sensory Evaluation of Irradiated Ground Beef Patties for the National School Lunch Program

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ABSTRACT: The 2002 Farm Bill allows irradiated ground beef to be distributed in the Natl. School Lunch Program (NSLP). Sensory properties of irradiated ground beef specified for the NSLP were evaluated. Frozen ground beef patties with 15% fat content were either not irradiated or irradiated at doses of 1.35 and 3.0 kGy. Aroma, taste, aftertaste, and texture as well as overall liking of cooked patties after 0 and 6 mo of storage were evaluated using nontrained panels. Results showed that irradiation had no significant ($P > 0.05$) effect on the ratings of any of the sensory attributes either at 0 or after 6 mo of storage. Average ratings of liking of aroma, taste, aftertaste, and overall were higher at 6 mo than at 0 mo.

Keywords: ground beef, ionizing radiation, sensory evaluation, schools

Introduction

More than 28 million children in the United States receive meals daily through the federal school meal programs. Children are an "at-risk" population, susceptible to food-borne illness due to their less-developed immune systems. Therefore, providing safe meals for the Natl. School Lunch Program (NSLP) is very important. The instances of food-borne outbreaks associated with the federal school lunch program are low (U.S. General Accounting Office [GAO 2003]). Among the 7390 food-borne outbreaks that were reported nationwide from 1990 to 1999, about 3% occurred in schools (GAO 2003). To reduce the risk of food-borne illness in schools, GAO recommended that the United States Dept. of Agriculture (USDA), Agricultural Marketing Service (AMS), and Food Nutrition Service to study the feasibility of purchasing and distributing irradiated meat and poultry products in the NSLP.

In response to the GAO recommendation and the 2002 Farm Bill, the AMS has published procurement specifications for irradiated ground beef for NSLP (AMS 2003). AMS specified that ground beef should contain an average of 15% fat (except Not-To-Exceed 10% ground beef) and be subjected to ionizing radiation dose that is no less than 1.35 kGy and no more than 3.0 kGy. In addition, it must be maintained in a frozen state from the time it leaves the freezers, throughout the irradiation process, and storage (AMS 2003). The irradiated products must have a "best if used by date" of 180 calendar days from the date of production. Irradiated ground beef is available on a voluntary basis to all school districts beginning in 2004.

There have been a number of studies on sensory evaluation of ground beef in recent years. Murano and others (1998) irradiated (2 kGy) and stored frozen ground beef patties (20% fat) in different packaging schemes for up to 7 d at -25°C . They found that packaging type and storage affected sensory attributes of irradiated ground beef, but no undesirable change was caused by irradiation. Ground beef patties irradiated under vacuum and stored in air

were more tender than the nonirradiated samples. Luchsinger and others (1997) evaluated irradiated (2.0 and 3.5 kGy) frozen ground beef (10% and 22% fat) using a trained panel and found that irradiation had no effect on flavor, texture, or aroma. Lopez-Gonzalez and others (2000), using a trained panel, found that irradiated (2 kGy) fresh ground beef (20% fat) had less beef flavor than the nonirradiated beef. There were no differences in other sensory attributes between irradiated and nonirradiated samples. Wheeler and others (1999), using both trained and consumer panels, evaluated ground beef (19% fat) after 27 to 29 d and 62 to 104 d, respectively, of storage at -28°C . They found that the trained panel rated irradiated (3 and 4.5 kGy) ground beef as having less beef flavor and aroma and more off-flavor; the consumer panel found that patties with 4.5 kGy were lower in taste than the nonirradiated patties. Giroux and others (2001), using a nontrained panel, found no difference in odor and taste between irradiated (up to 4 kGy) and nonirradiated ground beef patties (23% fat) during 7 d of storage at 4°C . Lorenzen and Heymann (2003) found that irradiation of frozen ground patties (fat content not defined) at 1.0 kGy had little effect on overall liking, tenderness, juiciness, and flavor of cooked patties. Vickers and Wang (2002) found that ratings of overall liking, flavor liking, and texture liking for irradiated (1.5 kGy) fresh ground beef (fat content not defined) did not differ from those of the nonirradiated patties. The rating of juiciness was higher in irradiated patties than the nonirradiated ones.

Despite the documented benefits of ionizing radiation for reduction of food-borne pathogens such as *Escherichia coli* O157:H7 (Olsen 1998; Thayer and others 1996) and a number of studies showing irradiation at doses up to 3.0 kGy had no negative effect on sensory attributes of ground beef, there are still concerns on acceptability of irradiated ground beef used in the NSLP. None of the studies targeted ground beef that was specified for NSLP as defined by the AMS. For example, fat content of the samples in some of the studies was not specified or differed from the NSLP targeted fat content (15%). Also long-term (6 mo) storage effect on irradiated ground beef is unclear.

Therefore, this study was conducted to evaluate the effects of irradiation on sensory properties of ground beef specified for the NSLP and to study the sensory quality of irradiated ground beef after 6 mo storage.

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Table 1—Gender and age distribution (% of total) of panelists

Storage time (mo)	Trial nr	Nr of panelists	Sex		Age group					
			Male (%)	Female (%)	<20	20 to 29	30 to 39	40 to 49	50 to 59	>60
0	1	77	67.5	32.5	19.5	24.7	13.0	19.5	19.5	3.9
0	2	53	60.4	39.6	17.0	30.2	5.7	20.8	20.8	5.7
6	1	60	70.0	30.0	0.0	13.3	15.0	38.3	23.3	10.0
6	2	64	65.6	34.4	0.0	18.8	18.8	32.8	21.9	7.9
Overall		254	66.1	33.9	9.5	21.7	13.4	27.6	21.3	6.7

Materials and Methods

Samples

Frozen ground beef patties (85 g in weight, 0.8 cm in thickness, 10 cm in dia) with 15% fat, used for NSLP and specified by AMS procurement, were provided by AMS. The patties were vacuum (4 mmHg) packaged in oxygen permeable film bags (B12A, Cryovac, Duncan, S.C., U.S.A.). The patties were stored at -18°C approximately 3 wk before being irradiated to 0, 1.35, and 3.0 kGy γ irradiation at -20°C . After irradiation, patties were stored at -18°C for 6 d (0 mo) or 6 mo before being cooked and evaluated.

Irradiation and dosimetry

Irradiation was conducted using a self-contained, Lockheed Corp. ^{137}Cs γ radiation source (Marietta, Ga., U.S.A.). The unit has 23 ^{137}Cs pencils placed in an annular array around a 63.5-cm-high stainless steel cylindrical chamber with a 22.9-cm internal dia. The dose rate was 0.093 kGy/min. The dose rate was established using alanine transfer dosimeters from the Natl. Institutes of Standards and Technology (Gaithersburg, Md., U.S.A.). Corrections for source decay were made monthly. Variations in radiation dose absorption were minimized by placing the samples within a uniform area of the radiation field and by using the same geometry for sample irradiation during the entire study. Routine dosimetry was performed in accordance with ISO/ASTM standard (ASTM 2002). The 5-mm dia alanine dosimeters were placed into 1.2 mL cryogenic vials (Nal-gene, Rochester, N.Y., U.S.A.), and the cryogenic vials were taped onto the samples prior to irradiation. After irradiation, the free-radical signals in the dosimeters were measured using a Bruker EMS 104 EPR Analyzer (Bruker Instruments, Rjeomstettem, Germany). Temperature (-20°C) in the radiation chamber was maintained by injecting the gas phase from a liquid nitrogen tank into the radiation chamber. Targeted doses were 0, 1.35, and 3.0 kGy. Measured doses were within 10% of the target doses.

Cooking and sensory evaluation

The ground beef patties were cooked from the frozen state in convection ovens (Model OV250, Cadco Ltd., Winsted, Conn., U.S.A.). Temperature setting for the ovens was 149°C (300°F). Actual oven temperature was 140 to 143°C . Ovens were prewarmed before use. Patties with different treatments were cooked in identical but separate ovens to avoid cross-contamination. The final cooked internal temperature was 80°C (176°F) monitored by a cooking thermometer (Model 362, Polder Inc., Port Chester, N.Y., U.S.A.). The internal temperature of patties was also verified using a NIST traceable digital thermometer (15-077-8, Control Co., Friendswood, Tex., U.S.A.). Typical cooking times were between 14 and 15 min. After cooking, the patties were cut into 4 wedges. The samples were kept at 55°C (131°F) for no more than 1.5 h in a lid-covered food warmer before being served.

Quantitative affective test of cooked ground beef was per-

formed at the sensory evaluation room of USDA's Eastern Regional Research Center (ERRC). Panelists consisted of ERRC employees and summer students and were informed of the nature of the samples. Before serving samples, questions about age and gender were asked. Samples were evaluated in environmentally controlled booths illuminated with indoor halogen PAR 30 1100 lumens, 75 watts, narrow floodlight lamps (Osram Sylvania Products Inc., Winchester, Ky., U.S.A.). Each sample was given a 3-digit numerical code and order of presentation was randomized. The panelists rated each sample for liking of aroma, taste, texture, aftertaste, and overall on 9-point fully labeled category scale (1 = dislike extremely to 9 = like extremely) using computer ballots (Compusense *five*, version 4.4, Compusense Inc., Guelph, Ontario, Canada). Drinking water and nonsalted crackers were provided, and panelists were asked to cleanse their palates with water and crackers before and between samples. A comment section was provided following each sample. Panelists were recruited so that the number of panelists for each session was above 50. Each panelist evaluated 3 samples in each session.

Experimental design and statistical analysis

The experiments were performed as a completely randomized block design. Experiments were repeated in 2 separate trials with a total of 4 sessions. Separate trials were conducted for 0 mo and 6 mo samples. Data were analyzed using statistical software (SAS, Version 8, SAS Inst. Inc, Cary, N.C., U.S.A.). The effects of storage, dose, and their interaction were analyzed using a generalized linear model performing a logistic regression analysis addressing the multinomial nature of the response (Stokes and others 2000).

Results and Discussion

The number of panelists that participated in the study was between 53 and 77 in the 4 sessions. There were always more male panelists than females in all of the sessions (Table 1). On average, roughly 2/3 of the panelists were males. A wide range of panelists from each age group participated in the study (Table 1). Among the panelists who participated in the 0 mo study, those younger than 20 were 19.5% and 17% of totals for trial 1 and 2, respectively, representing mostly high school students who worked temporarily in the summer. No teenage panelists were involved in the 6 mo study.

The average ratings on liking of aroma, taste, texture, aftertaste, and overall are shown in Table 2. No significant ($P > 0.05$) difference was found in the degree of liking of any attribute between nonirradiated samples and the 2 irradiated samples. Furthermore, there was no difference in the degree of liking of any quality attribute between the 2 irradiated samples (that is, 1.35 kGy and 3.0 kGy). The average ratings of liking for all the attributes were between 5 (neither like nor dislike) and 6 (like slightly). After 6 mo storage, irradiation at either dose did not significantly affect the ratings of liking of aroma, taste, texture, aftertaste, or overall. In general, the

Table 2—Effect of irradiation and storage on the degree of liking^a of ground beef patties irradiated at 0, 1.35, and 3 kGy^b

Storage time (mo)	Dose (kGy)	Aroma	Taste	Texture	Aftertaste	Overall
0	0	5.3 ± 1.6b	5.6 ± 1.7b	5.5 ± 1.7a	5.4 ± 1.6bc	5.5 ± 1.7bc
	1.35	5.2 ± 1.6b	5.8 ± 1.8ab	5.3 ± 1.8a	5.4 ± 1.6bc	5.6 ± 1.7abc
	3.0	5.2 ± 1.7b	5.6 ± 1.7b	5.2 ± 1.8a	5.3 ± 1.6c	5.4 ± 1.7c
6	0	5.6 ± 1.5ab	5.9 ± 1.7ab	5.5 ± 1.6a	5.7 ± 1.5ab	5.8 ± 1.6abc
	1.35	5.7 ± 1.4a	6.1 ± 1.5a	5.6 ± 1.5a	5.8 ± 1.5a	6.0 ± 1.5a
	3.0	5.5 ± 1.6ab	6.1 ± 1.8a	5.3 ± 1.6a	5.6 ± 1.6ab	5.9 ± 1.5ab
Overall storage effect ^c		*	NS	*	*	*

^aLiking scores are 9-point fully labeled category scales where 1 = dislike extremely and 9 = like extremely.

^bMeans with same letters are not significantly different ($P > 0.05$).

^c* is the overall significant ($P < 0.05$) effect of storage time and NS indicates nonsignificant effect of storage time.

ratings of liking of aroma, taste, aftertaste, and overall were significantly ($P < 0.05$) higher than those at 0 mo whereas no change in liking of texture was found during storage. Statistical analysis using the logistic regression analysis indicated that aroma liking for the 1.35 kGy at 6 mo was significantly ($P < 0.05$) higher than that of the corresponding sample (1.35 kGy) at 0 mo. The taste liking for the 3 kGy sample at 6 mo was higher than that at 0 mo. There was no evidence of any difference in texture liking due to storage. The 2 irradiated samples had significantly higher aftertaste liking than the corresponding samples at 0 mo. Overall liking was slightly higher for the 1.35 kGy ($P = 0.08$) and 3.0 kGy ($P = 0.05$) samples at 6 mo than the corresponding irradiated samples at 0 mo. The increased ratings of liking on some of the attributes at 6 mo may be due to the reduction of some undesirable properties of irradiated samples during storage or due to the seasonal changes of preference to cooked beef patties by the panelists. The test on 0 mo was conducted in the summer when ground beef patties were mostly consumed where the 6 mo study was conducted in the winter. Comments about all samples (both nonirradiated and irradiated) referred frequently to texture (chewy, tough, dry, and so on).

There was a large variation in the ratings of liking of all sensory attributes among panelists (Figure 1), which is typical in a consumer test, but the rating distributions were similar among the irradiated and nonirradiated patties. The median ratings of liking of aroma, taste, texture, aftertaste, and overall were 5, 6 to 7, 6 to 8, 6, and 7 to 8, respectively, regardless of irradiation treatments.

The ratings of liking of aroma, taste, texture, aftertaste, and overall by panelists younger than 20 were similar for irradiated and nonirradiated ground beef. (Table 3). Furthermore, there was no difference in the average ratings of liking of any attribute between the teenage panelists and the rest of the panels.

In the present study, we used AMS-specified ground beef with a fat content of 15%. The samples were cooked in convection ovens, similar to the practice commonly used in schools. Our results showed irradiation of frozen ground beef at doses of 1.35 and 3.0 kGy did not affect liking of the sensory attributes when evaluated 6 d after irradiation. The results were in line with many earlier studies involving fresh and frozen samples with little storage (Luchsinger and others 1997; Murano and others 1998; Wheeler and others 1999). Our study further showed that irradiation of ground beef did not affect liking of any of the sensory attributes even after 6 mo postirradiation storage at -18°C , the maximum storage time permitted by AMS.

Trained panels are generally more sensitive than nontrained ones and are able to detect trace differences between samples. Wheeler and others (1999) showed irradiated ground beef evaluated by a trained panel had less beef aroma and a higher off-flavor

score than nonirradiated samples while a consumer panel did not find any difference between the treatments. In the present study, we evaluated the liking of the sensory attributes, using a non-trained panel and found no difference in liking of any of the sensory attributes between irradiated and nonirradiated samples. A more sensitive test (a triangle test) involving 54 panelists was conducted on 0 mo ground beef to evaluate the difference between the

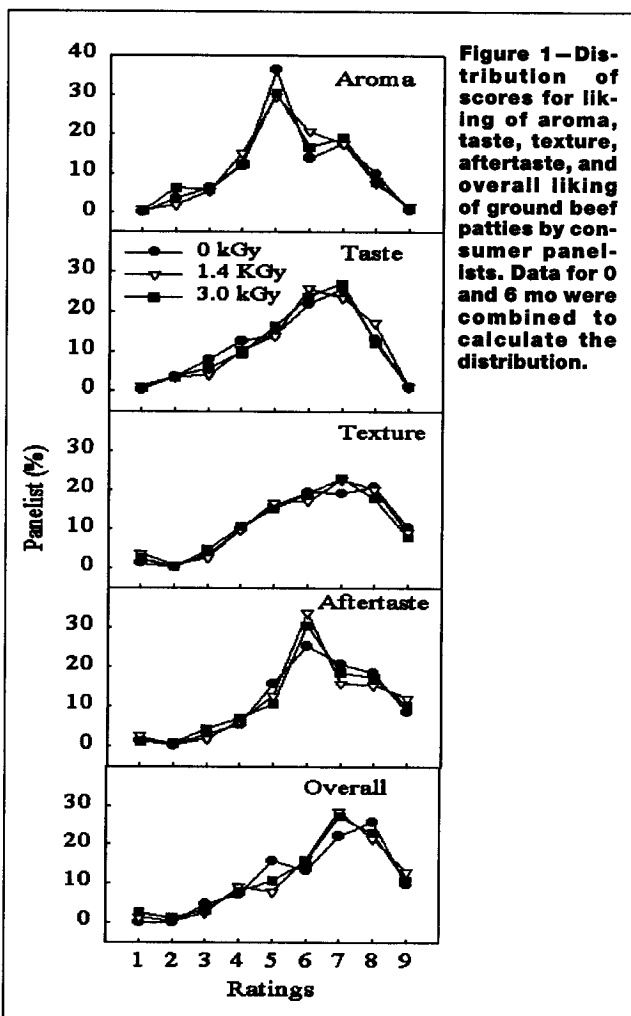


Figure 1—Distribution of scores for liking of aroma, taste, texture, aftertaste, and overall liking of ground beef patties by consumer panelists. Data for 0 and 6 mo were combined to calculate the distribution.

Table 3—Effect of irradiation and storage on the degree of liking^a of ground beef patties rated by the 24 teenage panelists at 0 mo^b

Dose (kGy)	Aroma	Taste	Texture	Aftertaste	Overall
0	5.3 ± 1.6a	5.6 ± 1.7a	5.5 ± 1.7a	5.4 ± 1.6a	5.5 ± 1.7a
1.35	5.3 ± 1.6a	5.8 ± 1.8a	5.3 ± 1.8a	5.4 ± 1.6a	5.6 ± 1.7a
3.0	5.2 ± 1.7a	5.6 ± 1.7a	5.2 ± 1.8a	5.3 ± 1.6a	5.4 ± 1.7a

^aLiking scores are 9-point fully labeled category scales where 1 = dislike extremely and 9 = like extremely.

^bMeans with same letters are not significantly different ($P > 0.05$).

2 irradiated samples and the controls. The correct responses out of 54 were 22 and 23 for 1.35 and 3.0 kGy, respectively. No significant ($P > 0.05$) differences were found, suggesting the difference between irradiated and nonirradiated ground beef was so little that consumers are unlikely to distinguish irradiated ground beef from the nonirradiated products.

In principle, sensory analysis should be performed by the population for whom the product is intended (Meilgaard and others 1999). For the ground beef intended for NSLP, ideally panelists should be K-12 students. However, due to limitations of logistics, parental consents and cognitive development of children, we did not attempt to secure a panel that consisted of only students. Children can give general feedback, but response to specific attributes requires a higher level of cognitive development than younger children are capable of (Moskowitz 1985). The teenage panelists who participated did not rate any difference in liking of aroma, taste, aftertaste, texture, and overall between irradiated and nonirradiated ground beef. Furthermore, no difference was found in the ratings of liking of the attributes by the teenagers and the rest of panelists.

Conclusions

Irradiation at doses up to 3 kGy did not affect the ratings of overall liking or liking of aroma, taste, texture, and aftertaste of ground beef patties used for NSLP, evaluated either immediately after irradiation or after 6 mo of storage at -18°C . Our results suggest that irradiation at doses specified by AMS did not affect the liking of sensory properties of the ground beef patties used in the NSLP.

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